Research Paper | Education | E-ISSN No : 2454-9916 | Volume : 10 | Issue : 8 | August 2024

FLOOD INUNDATION MAPPING OF GODAVARI RIVER BY USING 2D HEC-RAS MODEL

Tejaswini More[1], Dhanashri Patil[2], Rakhi Parpiyani[3], Rutuja Pardeshi[4], Vidya Saraf[5]

[1,2,3,4] Student, Department of Civil Engineering, Jalgaon, Maharashtra, India

[2] Assistant Professor, Department of Civil Engineering, Government College of Engineering, Jalgaon, Maharashtra, India

ABSTRACT

Due to increasing urbanization, there are various drastic changes taking place in environment these changes are hazardous for human being as well as animal and environment. Effect of environmental degradation can create environmental issues such as flood, drought etc. Out of this flood is the most common and disastrous hazard in the world. Present study utilizes 2D Unsteady flow modelling for flood inundation mapping in the lower Godavari basin for a reach length of 70 km from Sambaigudem in Telanagana district of Ramanujavaram to Damaracherla in Andhra Pradesh district of Nalgonda. For analysis of this 2D flow modelling and inundation mapping 30m resolution DEM is used. From ancient time majority of cities are developed near or on the banks of the river and these cities were affected due to flood during rainy season or due to the high intensity rainfall. As India is among the most vulnerable to flooding because of its geographical features. Therefore, this study is performed to analyze the flood plain and the extent of the affected areas present on or near the bank of Godavari River and provide mitigation measures for it.

KEYWORDS: HEC-RAS, Flood Mapping, Ras Mapper, 2D Unsteady Modelling, Hydrograph, Boundary Condition.

INTRODUCTION

In the last 50 years, urbanization has been increasing day by day. For development of any country urbanization is play an important role because the economic development of country depends on urbanization. In 2021, approximately a 35.39 % of the total population in India lived in cities. This migration trend from rural to urban areas shows an increase of urbanization by more than 4 percent in the last decade (2022), meaning people have moved away from rural areas to urban areas for finding the job. Around 50% or more of the world's population lives in urban areas. Due to urbanization, there are various changes are taking place in environment and these changes are hazards for human being, animals as well as for environment (Boyu Feng et al.2021). The degradation of environment can create environmental issues which leave the lasting impacts on the environment. Such as the flood, it is one of the major natural calamities which the world is facing in this 21st century therefore river flood inundation studies and floodplain modelling have made considerable use of

hydraulic flood models to prepare the flood risk map (Jian Cheng et al. 2009). Water security is greatly threatened by the growing frequency of flood occurrences brought on by urbanization and global climate change (Manqing Shao et al. 2020). In today's time human activities also responsible for the occurrence of flood. Floods are a natural disaster that the world is currently involved with in the 21st century. In the human ecology, extreme weather conditions brought on by the current effects of climate change as well as a number of unchecked human activities have become a major cause of floods. Worldwide, flooding is the most common, widely distributed, and devastating type of natural disaster. Flooding is frequently caused by excessive rainfall, especially in metropolitan areas with high runoff and low soil penetration rates. Flooding occurrences are more likely to occur in urban areas that are constructed next to or along river channels. Urban regions are more vulnerable to flooding, which is mostly brought on by malfunctioning drainage systems, fast conversion of land uses, lax regulations governing urban growth and the lack of appropriate structure or flood protection measure (Felix Nkeki et al.2022).

India is among the nation most vulnerable to flooding worldwide. India's cities are experiencing flooding increasingly frequently. These urban floods cause deaths, destroy livelihoods, and put governments in financial jeopardy. State Bank of India research from July of this year calculated the combined economic damage from the 2023 floods in North India and Cyclone Biparjoy in Gujarat to be between Rs 10,000 and Rs 15,000 crore. Modelling the flood plain is necessary in order to enable the proper actions for efficient flood mitigation to be taken beforehand. With the development of contemporary technology, flood modelling with complex software programs aids in estimating the amount of the flood at its submergence (Sunil Kute et al. 2014). Flood control is widely acknowledged as an effective means of reducing the negative effects, and recent research has aimed to develop a more robust and sustainable approach to flood management (Lihong Wang et al. 2022).

The Indian subcontinent's unique geography makes certain areas vulnerable to flooding. The snow-clad Himalaya in the north is home to one of the world's greatest glaciers, which feed several perennial rivers. These rivers form a huge plain inhabited by millions of Indians. The vast plains are vulnerable to flooding caused by swollen rivers during monsoon season. The average rainfall in India is 1150 mm, but this varies greatly

across the country, according to NIDM. The yearly rainfall Over 2500 mm of rainfall is recorded throughout the western coast, Western Ghats, Khasi hills, and Brahmaputra valley. River floods typically occur during the monsoon season and are linked to tropical storms, depressions, active monsoon conditions, and break monsoon events. Floods can be caused by a variety of factors, including excessive rainfall, cloud bursting, glacial lake outbursts, and tsunamis. According to the Central Water Commission's Vulnerability Atlas of Flood Zones in India, flood-prone areas include the Indo-Ganga-Brahmaputra plain and coastal areas in Eastern and Western regions as shown in fig no.1. A river flood occurs when water from its tributaries accumulates. Rivers deposit silt and sand on their beds. Deposited slits slow the flow of the river, causing it to extend horizontally and submerge surrounding habitats. Flooding in flood-prone states is mostly caused by land depression and low-pressure zones (Prakash Tripathi 2015) (Nikumbh T.K et al 2019).

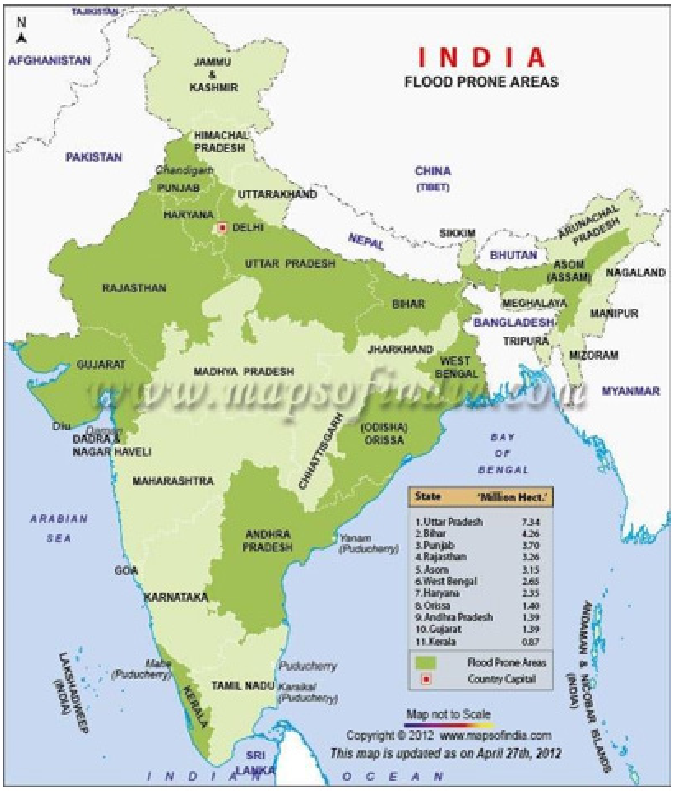

Fig no.1 – Flood prone areas in India

2. STUDY AREA

The Godavari, also referred to as the "Dakshina Ganga," is the biggest river on the Indian peninsula. The Godavari Basin occupies almost 9.5 percent of the country's total land area, making it the second largest basin after the Ganges basin. The Godavari River Basin (GRB) is categorized into upper, middle and lower river basins, and the Lower Godavari Basin (LGB) occupies nearly 28% of the area of the GRB (Vimal Chandra et al. 2021). The river traverses the Deccan Plateau from the Western to the Eastern Ghats, rising in the Sahyadris at 1,067 meters above mean sea level close to Trimbakeshwar in the Nashik district of Maharashtra. The basin is located on the Deccan Plateau between latitudes 16°19' N and 22°34' N and longitudes 73°24' E to 83°4' E.

The main river separates the states of Telangana and Chattisgarh as well as Telangana and Maharashtra. The river is 1,465 km long overall. The main river discharges into the Bay of Bengal after passing through the states of Telangana, Maharashtra, Chhattisgarh, and Andhra Pradesh. The Gautami and Vasishta rivers are the result of the river's division at Dowlaiswaram. There's the Godavari Central Delta between the two. The Godavari River flows through Telangana and Andhra Pradesh for around 772 kilometers. This study analyses the Godavari River's course from Sambaigudem (18°00'20.59″ N, 80°45'32.47″ E) in the Telangana district of Ramanujavaram to Damaracherla (17°35'50.66″ N, 81°03'42.81″ E) in the Andhra Pradesh district of Nalgonda. The study area is shown in the fig no. 2

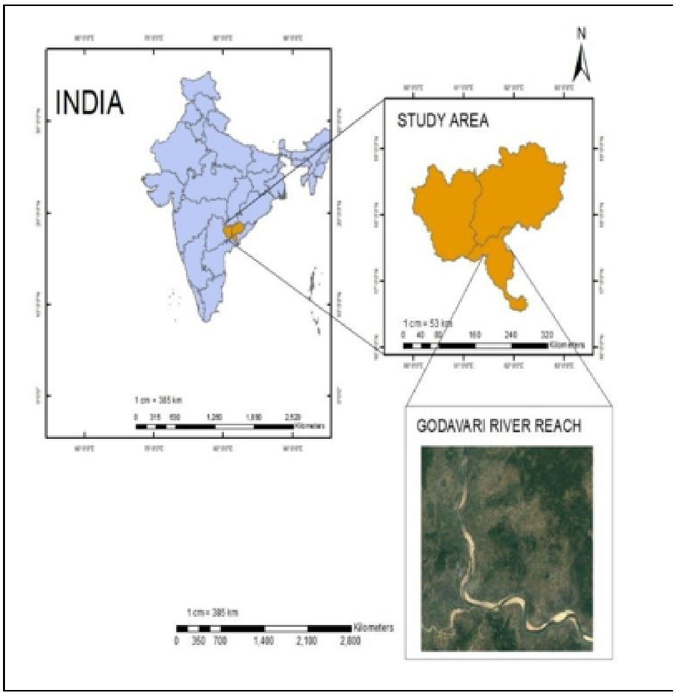

Fig no. 2 – Map showing study area

3. DATA COLLECTION AND PREPARATION

For creating 2D Flow HEC-RAS model different types of data is collected from various sources. This data includes Digital elevation model, Discharge data, Projection file of that study area and manning's roughness coefficient. This data serves as the foundation for the output and evaluation of model. The data required for simulation is collected as per the sources shown in the table no. 1

Sr No	Data Type	Data Source	Remark
1	DEM	Open topography	30m resolution
2	Discharge data	WRIS	Jan- Dec 2010 & 2018
3	Projection file	Spatial reference	UTM Zone 44N
4	Manning's roughness coef-ficient	HECRAS 2D user manual	Based on NLCD type

Table No.1 – Data type and it's sources

4. METHODOLOGY

Hydraulic modelling and inundation mapping are carried out with RAS Mapper, a spatial data integration and mapping tool in HEC-RAS. HEC-RAS Mapper facilitates the development of RAS terrains, layout of geometric data, extraction of terrain data, and demonstrate of results via maps and tables (Komal Vashist et al. 2023).

In this research, monthly discharge data is used for comparing two-year flow for time interval of 1st Jan 2010 to 31st Dec 2010 and from 1st Jan 2018 to 31st Dec 2018. As per past flow data, most severe flooding events occurred in Godavari at Bhadrachalam and nearby cities on Jun 1986 and Jun 2022 therefore 2D flow modelling is performed on this region by using the flow hydrographs as shown in the fig no.3 and Fig.no 4 for year 2010 and 2018

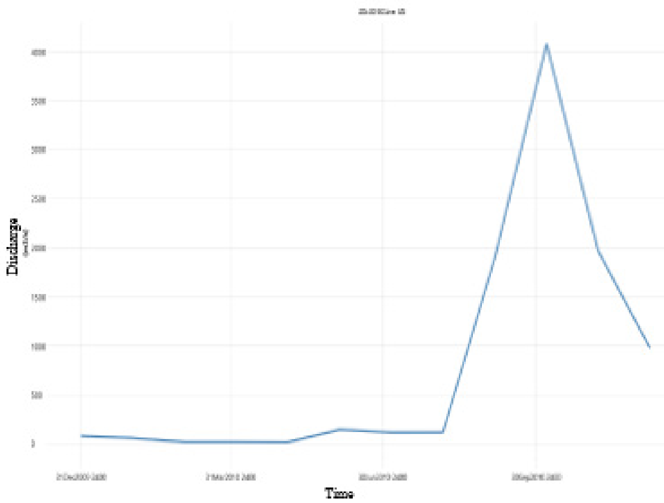

Fig no .3 – Flow hydrograph for year 2010

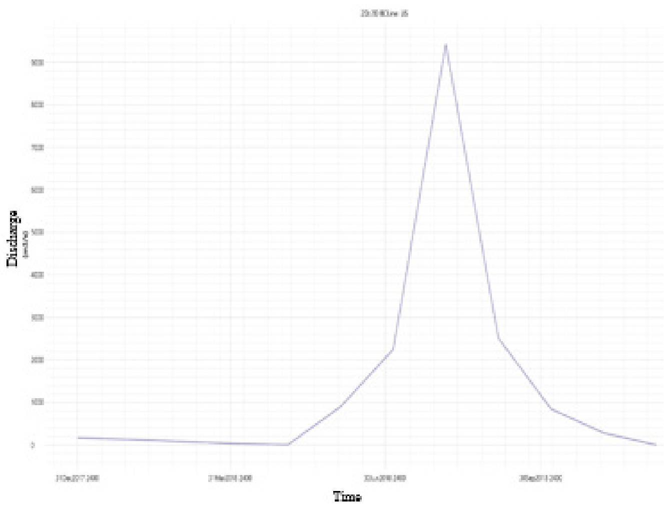

Fig no .4 – Flow hydrograph for year 2018

4.1 Creating terrain layer

For creating new Ras terrain layer in Ras mapper, the projection file (WGS 1984 Zone UTM 44 N) is downloaded from spatial reference and imported to assign the co-ordinates to the study area through projection tool Digital elevation model (DEM) of 30m resolution is downloaded from open topography and imported to Ras mapper as shown in fig no.5.

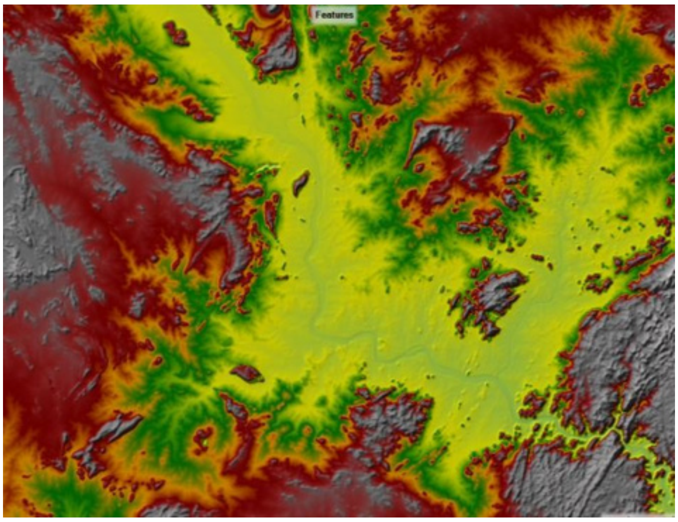

Fig no. 5 – Ras terrain layer

4.2 2D flow area Mesh generation

To generate the 2D flow mesh a new geometry is created in Ras mapper through geometries tool and the mesh is created it consist of 256844 number of cells having average face length of each cell is 100 m (i.e. dx/dy) as shown in fig no.6. The 2D flow mesh is created for the area which is possibly affected in past flood events or it may also be modified for the flow conditions of a that area.

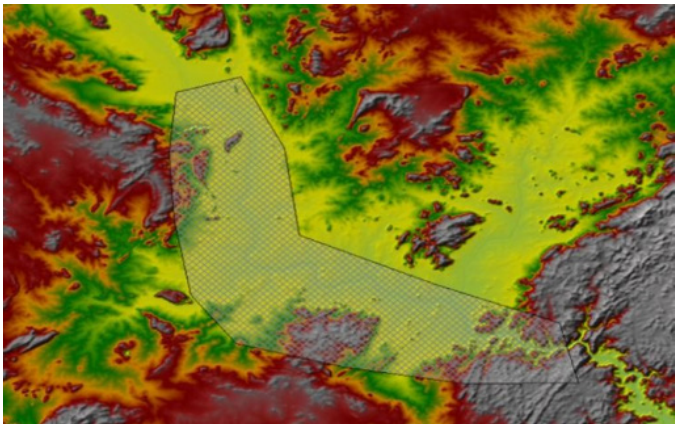

Fig no. 6 – 2D flow area with generated mesh

4.3 Application of manning's roughness coefficient

Manning's roughness coefficient is used to indicate the average roughness of a channel, which is provide resistance to the flow of water and affects its velocity therefore for velocity profile plot it's very important to consider the manning's roughness coefficient. Its value depends on the various factor such as type of vegetation, surface roughness etc. for this study manning's roughness coefficient is taken from HEC-RAS 2D user's manual based on the NLCD (National Land Cover Database) type and checked with help of previous research done on this river (Vimal Sharma et al 2021).

4.4 Defining boundary conditions

For generated 2D flow area upstream and downstream boundary conditions are added through the geometric data editor tool (Rahul Agarwal et al. 2016). In this study the flow hydrograph is used for the upstream boundary condition and the normal depth is used for the downstream boundary condition as shown in fig no.7. Normal depth in this software represents the average slope of a channel (i.e. 0.008) which is calculated from the Ras mapper.

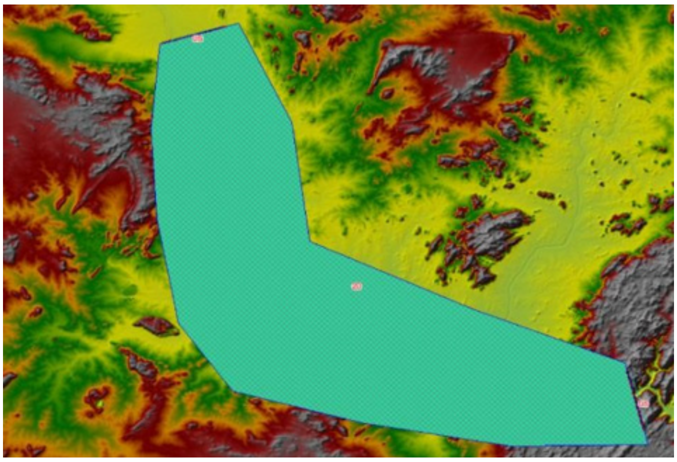

Fig no. 7 – 2D flow mesh with boundary conditions

4.5 Model simulation

For the unsteady flow analysis, specific programs need to be supplied, including the geometry preprocessor, unsteady flow simulation, postprocessor, flood plain mapping, and simulation period. For the simulations, the computational parameters including the computation interval is provided as one hour and hydrograph output interval, mapping output interval, detailed output interval is provided as one day (Patel et al. 2019). In this software the results of model depend on the hydraulic properties between two successive time steps, large time steps create the instability issues due to an excessively large change in hydraulic property between two successive time steps. Too small-time steps will also result in increase in the computation time. For the accuracy and stability of model the time step is selected as per the criteria of courant condition. The principal for selecting the time step is that the courant number is kept close to 1 and not larger than 5 for diffusive wave equation and 3 for full momentum equation (Gaurav Dahal et al 2021). Here the Theta weightage factor is used as 1 for simulation, accuracy and stability of any model is depend on this.

5. RESULTS AND DISCUSSION

For this research work 70 km river reach is taken to analyze the 2D Flow modelling and inundation mapping of the lower Godavari River by using HEC-RAS. For this modelling diffusive wave equation is used for simulation in which finite volume approximation is considered. In this software the output results of 2D model are observed in the form of inundated area and affected area, velocity, water surface elevation (i.e. water depth) using Ras Mapper tool in HEC-RAS (Azaz Khan et al. 2020)

Comparison of 2010 and 2018-year flood depth map

It is observed in the 2010-year flow data depth of flooded water at Godavari River reach in study area is 55.92 m and in 2018 year is 56.45. (Fig. 7 & 8). We have simulated both flood year data in RAS-mapper and developed the inundation map for both 2010-year flood depth and 2018-year flood depth and are shown as in Fig. 9 and Fig.10. From 2010 to 2018 the flood water depth is increased by 0.53m.

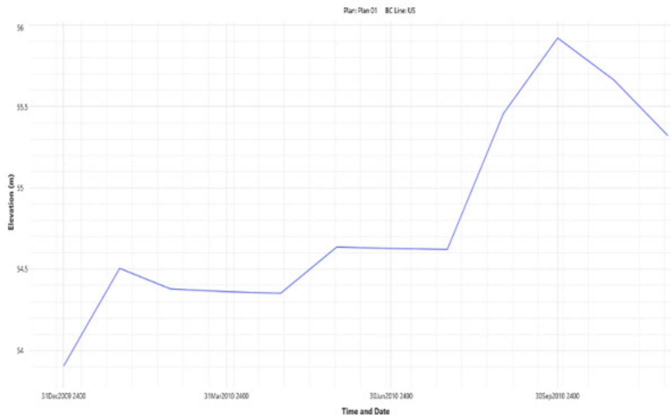

Fig no. 8 - Observed water surface elevation for 2010

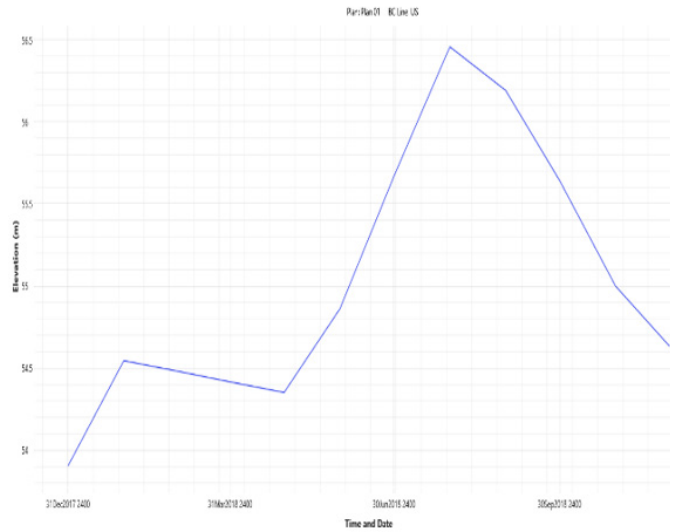

Fig no. 9 - Observed water surface elevation for 2018

Comparison of 2010 and 2018-Year Velocity map for maximum discharge

For year 2010 the velocity is greater than the 15 m/s for maximum flow value which is generally Observed during the rainy season months i.e. August, September and October, having the highest discharge of 4078.975 m3/s (cubic meter per second) on 6 October 2010 (Fig no.10). For year 2018 the velocity is greater than 100 m/s for maximum flow value of 7817.704 m3/s which is observed on 7 August 2018 (Fig no.11). As compare to 2010 the velocity for 2018 year is much greater.

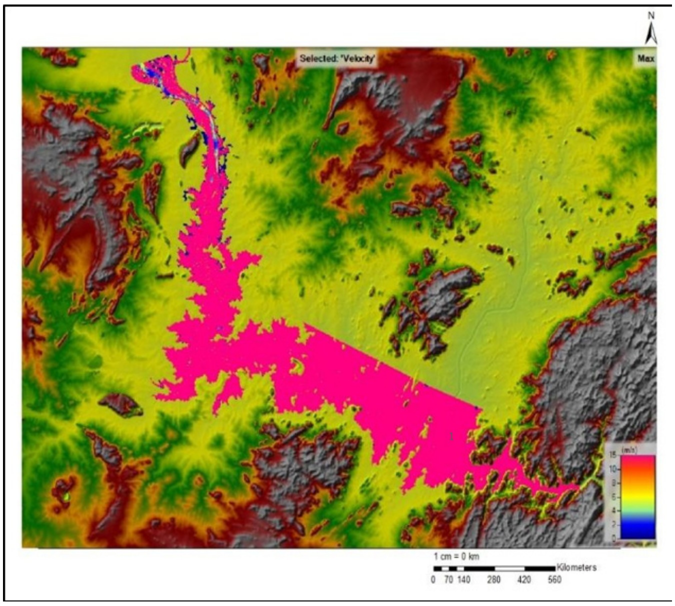

Fig no. 10 – Velocity map for year 2010

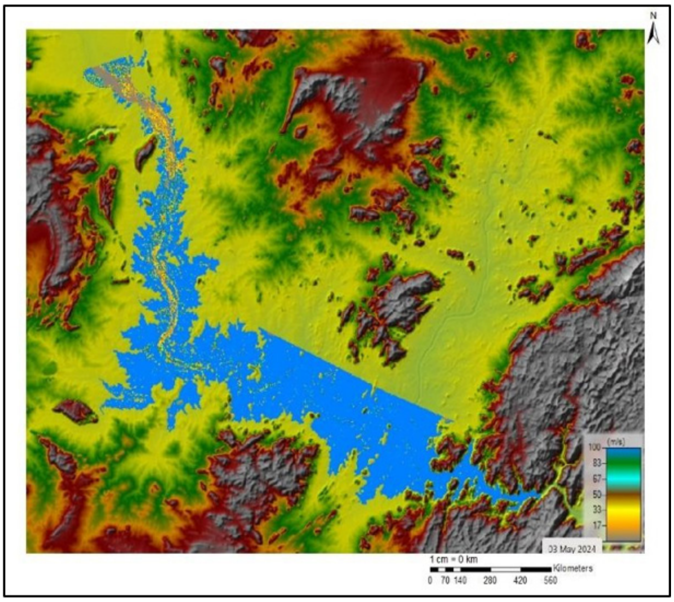

Fig no. 11 - Velocity map for year 2018

Comparison of 2010 and 2018-Year Flow water depth map for maximum discharge

For both year 2010 & 2018 flow water depth is greater than 15m as shown in the fig no.12 and 13 with dark blue color indicating the water depth. for year 2018 flow water depth is more because of increase in discharge of a river due to various factor such as climate change, change in land use etc. As per the output water depth map generated in Ras Mapper it is observed that the water depth is maximum at the downstream side of the Bhadrachalam due to sudden change in geographical feature of that region.

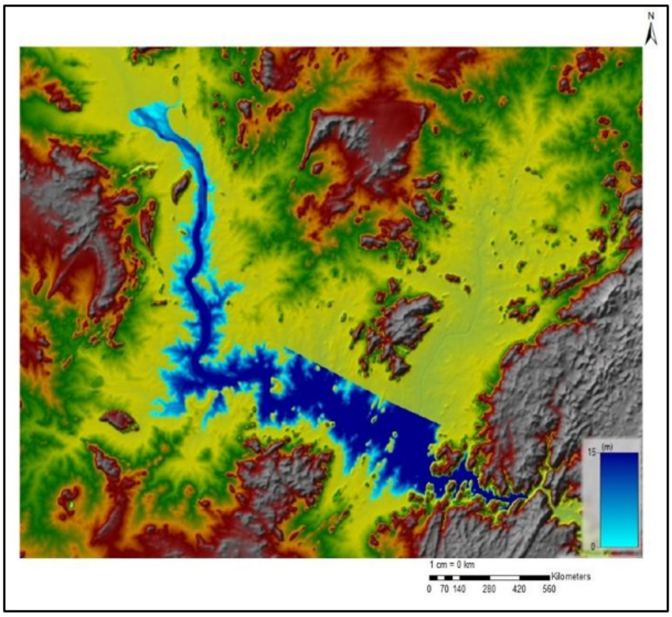

Fig no. 12 - Observed flow water depth1 for year 2010

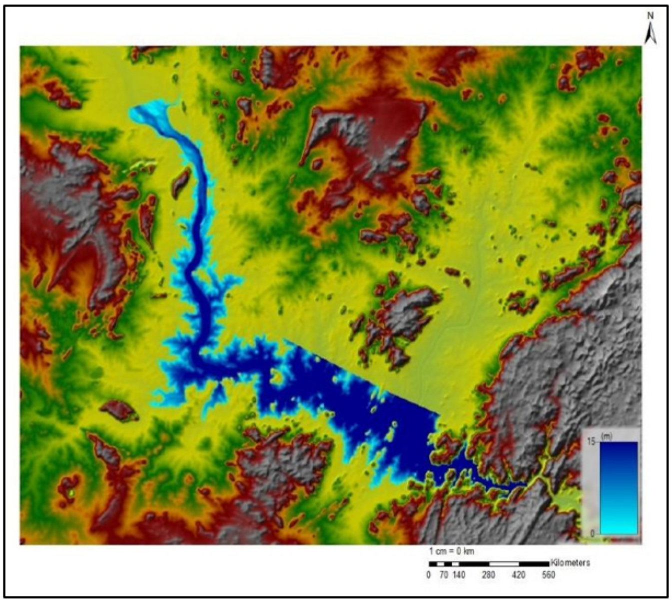

Fig no. 13 - Observed flow water depth for year 2018

Comparison of 2010 and 2018-Year flow Inundation boundary map

From the inundation mapping for year 2010 and 2018 it is observed that there is gradual increase of inundation area it may be due to various factor such as climate change, more intense rainfall for that particular area or due to the change in the land cover. As per the inundation maps shown in fig no. 14 and 15 it is observed that Mothepattinagar, Sarapaka, Reddy Palem and Burgampadu villages of Telangana state and Bhadrachalam, Seetapuram, Gundala, Rayanapeta, chowdavaram, Kapavaram and Damaracherla of Andhra Pradesh state were most affected areas due to the flood. But during the year 2010 least area is affected (Fig no. 14) as compare to the 2018 (Fig no.15)

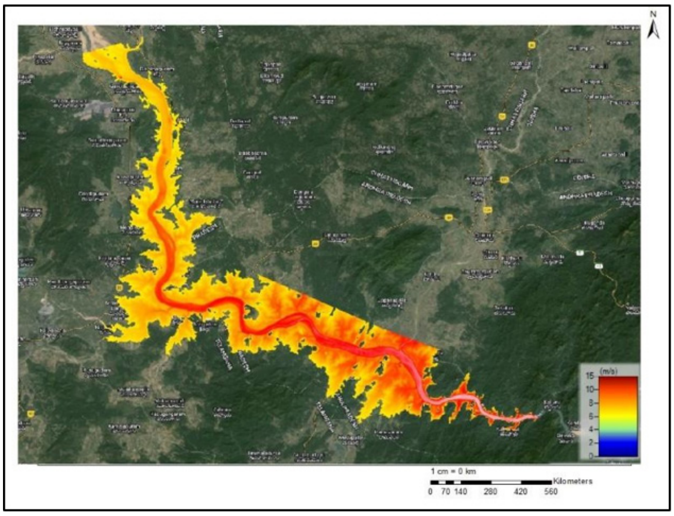

Fig no. 14 - Observed flow Inundation Boundary Map for 2010

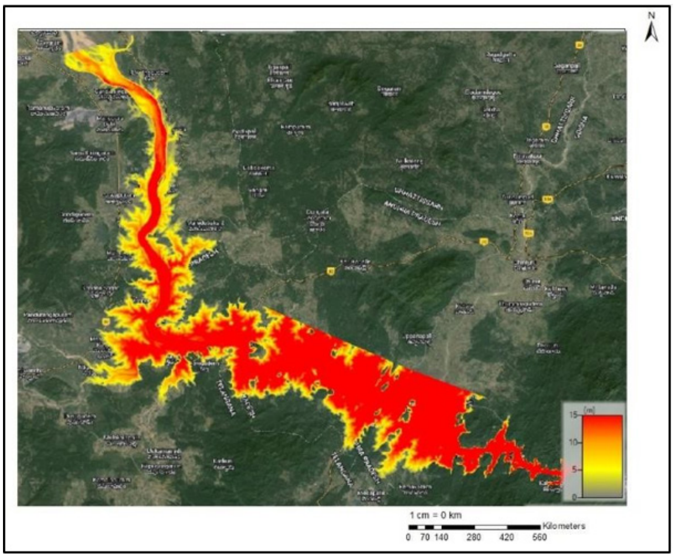

Fig no. 15 - Observed flow Inundation Boundary Map for 2018

6. CONCLUSION

This 2D unsteady hydraulic model is performed by using the HEC-RAS software version 6.5 which is developed by the U.S. Army corps of Engineers for lower Godavari basin from the Sambaigudem in the Telangana district of Ramanujavaram to Damaracherla in the Andhra Pradesh district of Nalgonda. Total river reach length of 70 km is analyzed to compare the output data such as velocity, water surface elevation, water depth and inundated boundary area for year 2010 and 2018 monthly flow hydrograph is used. For simulation the computation interval is kept as one hour and hydrograph output interval, mapping output interval and detailed output interval is kept as one day because time series affects the simulation. If large time series is used it can create issues and instability of model while the small time series leads to increase in the computation time therefore for correct or ideal time step is selected as per the courant condition. From this analysis following conclusion can be drawn.

1. For the year 2010 and 2018 the maximum water depth is 55.926 m and 56.45 m are observed during the monsoon of September and August. From the year 2010 there is gradual increase in the water depth as 0.53 m in the year 2018.
2. The peak flow for 2010 year is 4078.975 m3/s and for year 2018 is 7817.704 m3/s. for this peak flow the surrounding area during September to October is affected and the velocity of water is also maximum during this period.
3. As per the analysis it is observed that in year 2010 flood affected area is less as compare to the year 2018.
4. It is detected that Mothepattinagar, Sarapaka, Reddy Palem and Burgampadu villages of Telangana state and Bhadrachalam, Seetapuram, Gundala, Rayanapeta, chowdavaram, Kapavaram and Damaracherla of Andhra Pradesh state were most affected areas due to the flood during the August month of 2018.

From this 2D unsteady flow modelling analysis we can reduce the impact of flood by constructing the flood wall and improving the river channel. To avoid the effect of flood on human settlement it is suggested that the settlement must be restricted near the flood plain boundary or on the inundation area. We can use the inundation map generated in HEC-RAS to prepare the flood risk map and to prepare the mitigation strategies.

REFERENCES

1. Feng, B., Zhang, Y., & Bourke, R. (2021). Urbanization impacts on flood risks based on urban growth data and coupled flood models. Natural Hazards, 106(1), 613–627. https://doi.org/10.1007/s11069-020-04480-0
2. Chen, J., Hill, A., & Urbano, L. D. (2009). A GIS-based model for urban flood inundation. Journal of Hydrology, 373(1–2), 184–192. https://doi.org/10.1016/j.jhydrol.2009.04.021
3. Shao, M., Zhao, G., Kao, S., Cuo, L., Rankin, C., & Gao, H. (2020). Quantifying the effects of urbanization on floods in a changing environment to promote water security — A case study of two adjacent basins in Texas. Journal of Hydrology, 589, 125154. https://doi.org/10.1016/j.jhydrol.2020.125154
4. Nkeki, F. N., Innocent, B. E., & Ganiy, A. I. (2022). Flood risk mapping and urban infrastructural susceptibility assessment using a GIS and analytic hierarchical raster fusion approach in the Ona River Basin, Nigeria. International Journal of Disaster Risk Reduction, 77, 103097. https://doi.org/10.1016/j.ijdrr.2022.103097
5. Sunil Kute. (2014). Flood modelling of river Godavari using HEC-RAS. International Journal of Research in Engineering and Technology, 03(21), 81–87. https://doi.org/10.15623/ijret.2014.0321017
6. Wang, M., & Cui, M. (2022). A review of the flood management: From flood control to Flood resilience. Heliyon,8(11),11763. https://api.semanticscholar.org/CorpusID:2540 04531
7. Tripathi, M. (2015). Flood disaster in India: An analysis of trend and preparedness. Interdisciplinary Journal of Contemporary Research, 2(2393–8358), 4. https://doi.org/10.1016/j.jhydrol.2020.124904
8. Nikumbh, T. K, & Regulwar, D.G (2019). Integrated hecras/hechms and gis model for flood simulation of upper Godavari River, Nashik, India. Researchgate. https://www.researchgate.net/publication/33360 2731
9. Sharma, V., & Regonda, S. K. (2021). Two- Dimensional flood inundation modeling in the Godavari River Basin, India—Insights on model output uncertainty. Water, 13(2), 191. https://doi.org/10.3390/w13020191

10. Vashist, K., & Singh, K. K. (2023, April 1). HEC-RAS 2D modeling for flood inundation mapping: a case study of the Krishna River Basin. Water Practice & Technology, 18(4), 831–844. https://doi.org/10.2166/wpt.2023.048
11. Agarwal, R., & Regulwar, D. (2016). Flood analysis of Dhudhana River in Upper Godavari Basin using HEC-RAS. International Journal of Engineering Research, 5(2319–6890), 2347– 5013. https://doi.org/10.17950/ijer/v5i1/044
12. K B, P., & S.M, Y. (2019). One Dimensional Unsteady Flow Analysis Using HEC-RAS Modelling Approach for Flood in Navsari City. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3351780.
13. Dahal, G., & Adhikari, S. (Eds.). (2021). Optimization of model parameters of HEC-RAS 2D model on flood inundation mapping: A case study of Kankai River Basin (10th ed., Vol. 10). IOE Graduate Conference. https://www.researchgate.net/publication/35902 3789
14. Agnihotr, A. K. I. P. a. P. G. (2020). 2-D unsteady flow modelling and inundation mapping for lower region of Purna Basin using HEC-RAS. DOAJ (DOAJ: Directory of Open Access Journals). https://doaj.org/article/65ea4d4b9fbf45c496ba8 aef1edad7bd